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THE AUTOINSTRUCTIONAL MATERIALS IN THIS TEXT WERE PREPARED FOR USE IN AN EXPERIMENTAL STUDY, OFFERING SELF-TUTORING MATERIAL FOR LEARNING ATOMIC PHYSICS. THE TOPICS COVERED ARE (1) NUCLEAR BINDING ENERGY, (2) DISCOVERY OF RADIOACTIVITY, (3) RADIOACTIVE RADIATIONS, (4) ALPHA AND BETA DECAY, (5) BETA DECAY REACTIONS, (6) RADIOACTIVE DATING AND RADIATION COUNTERS, AND (7) PARTICLE ACCELERATORS. (RS)

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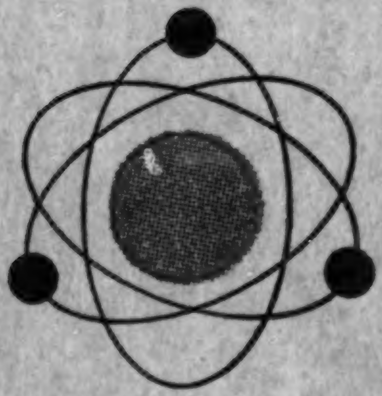
ATOMIC PHYSICS

AN AUTO-INSTRUCTIONAL PROGRAM

David J. Klaus and William A. Deterline

VOLUME 3



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David J. Klaus and William A. Deterline

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Pittsburgh Pennsylvania

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These materials were prepared for use in an experimental study of the self-tutoring approach in education. Further information concerning the design of the study and the resulting data are contained in reports available from the American Institute for Research.

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Name ______________________

Grade ____________ Age ______

School ______________________

①

UNIT N - Nuclear Binding Energy

plus review of Unit M

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

②

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER N-2

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER N-12

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER N-22

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER N-32

END OF UNIT

START HERE

rM-1 The total mass of the particles after a nuclear reaction is •__________ as the total mass ••__________ __________.

③

$$_2He^4 + {}_7N^{14} \longrightarrow {}_8O^{17} + {}_1p^1 + \text{energy}$$

N-2 Mass is a form of energy, and energy is a •__________ __________. The precise relationship between mass and energy is stated by Einstein's •__________ equation.

N-12 The energy that holds nucleons together in a nucleus is called •__________.

N-22 Two protons plus two neutrons have a total mass of 4.034 amu, while $_2He^4$ has a mass of 4.003 amu. When two protons and two neutrons combine to form $_2He^4$, #______ amu disappears.

$$\boxed{\begin{array}{rl} 2\ {}_1p^1 + 2\ {}_0n^1 = & 4.034 \text{ amu} \\ {}_2He^4 = & \underline{4.003 \text{ amu}} \\ & .031 \text{ amu} \end{array}}$$

N-32 Nuclei are held tightly together because ••__________ __________.

n-1

nuclear reaction
energy

n-11

binding energy

n-21

two protons and two neutrons
4.034

n-31

mass of the nucleons making up that nucleus

rm-1

not the same
before the reaction

n-2

form of mass
mass-energy

n-12

(nuclear) binding energy

n-22

.031

n-32

of nuclear binding energy (because some mass has been converted to energy which binds the nucleus together)

N-1 When mass disappears in a * ______________________________ , some __________ is always released.

⑨

N-11 The energy needed to hold the nucleus together is called nuclear binding energy. Although its exact nature is not known, the amount of nuclear * ______________________ in a nucleus can be precisely determined.

N-21 The mass of a proton is 1.008 amu, and the mass of a neutron is 1.009 amu. An alpha particle consists of ** ______________________________ which, by themselves, have a total mass of * ________ amu.

$_1p^1$	1.008 amu
$_1p^1$	1.008 amu
$_0n^1$	1.009 amu
$_0n^1$	1.009 amu
Total	4.034 amu

N-31 The mass of a nucleus is always less than the ** ____ .

---

rM-2 In the reaction, ${}_2He^4 + {}_4Be^9 \longrightarrow {}_0n^1 + {}_6C^{12}$, there is more mass before than after the ________; thus, some mass has ________.

⑦

N-3 The conversion of mass to ________ is important in understanding nuclear reactions. The conversion of • ________ ________ also helps to explain how nuclei are held together.

N-13 When nucleons combine to form a ________, some of their mass is converted to binding energy which •• ________ ________.

N-23 The mass of every nucleus is less than the total ________ of its separate nucleons because some of the ________ of the nucleons was converted to nuclear • ________ ________.

N-33 The force of repulsion between ________ charges and the force of attraction between ________ charges affects the penetrating power of a particle.

rm-9

the mass of the particles after the reaction

⑧

n-10

binding (nuclear)
protons

n-20

4

n-30

nucleus
nuclear binding

rm-2

reaction

disappeared (been lost)

---

n-3

energy

mass to energy

---

n-13

nucleus

holds the nucleus together

---

n-23

mass

mass

binding energy

---

n-33

like

unlike

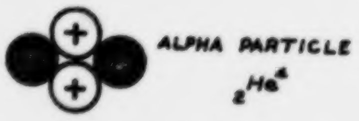
rM-9 The mass of the particles before the reaction, ${}_3Li^7 + {}_1p^1 \longrightarrow {}_2He^4 + {}_2He^4$, is .019 amu greater than ☐** ☐.

01

Before	${}_3Li^7 + {}_1p^1$	8.024 amu
After	${}_2He^4 + {}_2He^4$	8.005 amu
		.019 amu

N-10 The force or "glue" holding the nucleus together is called a binding force. This ☐ force prevents ☐ in the nucleus from moving apart.

N-20 As an example, we can measure the amount of binding energy which binds an alpha particle together. An alpha particle consists of a total of ☐# nucleons.



N-30 Mass can disappear in a reaction and also when nucleons are combined to form a ☐. The mass that disappears in a nucleus is converted into ☐* energy.

rM-3 In any nuclear reaction, energy is released whenever ________ disappears. The ________ that disappeared has been *________________.

⑪

N-4 Atomic nuclei consist of *________________ ________. The positively charged ________ and the uncharged ________ are held tightly together in a nucleus.

N-14 Nuclear ________ energy comes from some of the mass of the nucleons; that is, part of the ______ of the particles making up a nucleus has been converted to *________________ ________.

N-24 The mass of $_2He^4$ is approximately .030 amu less than the mass of two protons and two neutrons measured separately because some **________________________________ ________________________________ ________________________.

N-34 Particles that are very penetrating will easily pass ________ matter. Particles that are not very ________ do not **________________________.

rm-8

proton
alpha particles

⑫

n-9

force of repulsion

n-19

mass-energy
binding energy

n-29

mass disappears
energy

rm-3

mass
mass
converted (changed) to energy

(13)

---

n-4

protons and neutrons
protons
neutrons

---

n-14

binding
mass
binding energy (nuclear binding energy)

---

n-24

of the mass of the nucleons has been converted to nuclear binding energy

---

n-34

through
penetrating
easily pass through matter

rM-8 In the nuclear reaction ${}_3\mathrm{Li}^7 + {}_1\mathrm{p}^1 \longrightarrow {}_2\mathrm{He}^4 + {}_2\mathrm{He}^4$, a lithium atom and a ______ are changed to two ______ ______.

⑭

N-9 Protons are held together by a nuclear force which overcomes the ______ between like charges.

N-19 Einstein's ______ equation makes it possible to determine exactly how much nuclear ______ ______ is used to hold a nucleus together.

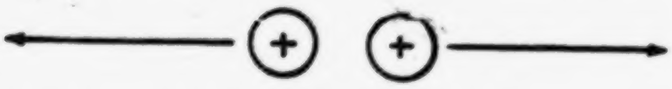
N-29 Energy is produced whenever ______ ______. In a nuclear reaction in which mass disappears, ______ can be released in the form of motion of the particles.

---

rM-4 Mass may be converted to ________, and ________ can be ________ into mass during a nuclear reaction.

⑮

N-5 Like charges repel each other. Because all protons are positively charged, they will tend to ________ each other.



N-15 Since part of the mass of the particles making up a nucleus has been converted into ________ ________, a nucleus always has ________ than the particles which formed it.

N-25 Nuclear binding energy is measured in Mev. Mev, you remember, stands for million ________.

N-35 Charged particles are ________ very penetrating because they are slowed down by being attracted and repelled by ________ ________.

rm-7

atomic mass units
million electron volts

⑨①

---

n-8

together
push them apart (repel them)

---

n-18

mass of the particles (nucleons)

---

n-28

mass-energy
$E = mc^2$

---

rm-4

energy
energy
converted (changed)

(17)

n-5

repel

n-15

nuclear binding energy
less mass

n-25

electron volts

n-35

not
other charged particles

rM-7 In describing the mass-energy changes in a nuclear reaction, mass is expressed in amu, that is, [* ____________ ____________], and energy is expressed in Mev, that is, [* ____________ ____________].

N-8 The force of repulsion between two protons close together is about 40 pounds in strength. Protons are held [____________] in a nucleus in spite of this force which tends to [* ____________ ____________].

N-18 Nuclear binding energy is energy converted from some of the [** ________________________] making up the nucleus.

N-28 The amount of binding energy in a nucleus can be determined from Einstein's [* ________________] equation, which is written [$ ______].

---

rM-5 Einstein's mass-energy equation, $E=mc^2$ describes the precise relationship between *____________________.

⑲

N-6 A force of repulsion exists between ________ charges. Because the protons in a nucleus are all positively charged, a *____________________ exists between them.

N-16 A nucleus has ________ mass than the total mass of the particles making up the nucleus. The difference in mass has been converted to *____________________ energy.

N-26 The .030 amu which is converted to nuclear ____________ energy in an alpha particle is equivalent to 28 million electron volts, written 28 \$_____.

N-36 Neutrons are far more ______________ than protons because **____.

rm-6

mass-energy
mc^2
large amount of energy

⑳

---

n-7

force of repulsion

---

n-17

nuclear binding energy
less mass

---

n-27

binding energy
mass of the nucleons (mass of protons and neutrons)

---

rm-5

mass and energy

---

n-6

like

force of repulsion

---

n-16

less

nuclear binding

---

n-26

binding

Mev

---

n-36

penetrating

neutrons are uncharged and are not slowed down by charged particles in their path rM-6 Einstein's [*] equation is written E=[$]. The equation states that a very small amount of mass can be converted to a very [**] [ ].

㉒

N-7 Protons stay tightly packed together in a nucleus in spite of the [*] between them.

N-17 Because some of the mass has been converted to [*], a complete nucleus always has [*] than the total mass of the particles making up that nucleus.

N-27 The amount of nuclear [*] holding an alpha particle together is 28 Mev. This energy was converted from some of the [**] which make up the nucleus.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rM-6

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER N-7

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER N-17

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER N-27

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER

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(25)

UNIT O - Discovery of Radioactivity

plus review of Unit N

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 0-10

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 0-24

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 0-38

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 0-52

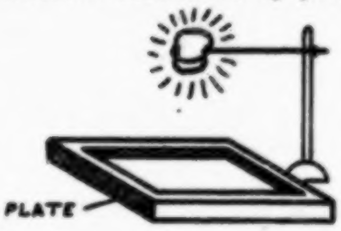
END OF UNIT

START HERE

rN-1 All protons have a ______ electrical charge. In spite of the force of ______ that exists between like charges, protons are held tightly together in a ______.

㉗

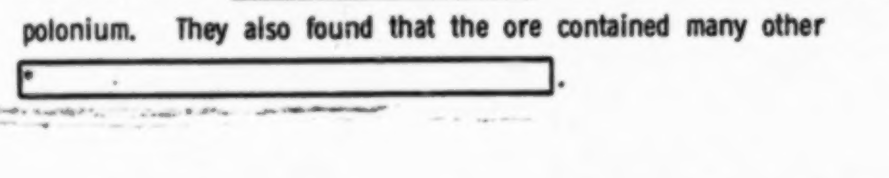
0-10 Becquerel studied phosphorescent substances by placing them near photographic plates in a dark room. Substances which were ______ would expose or darken the plate because they ______.



0-24 While processing uranium ore, the Curies discovered the first known ______ element, which they named polonium. They also found that the ore contained many other ______.

0-38 A radioactive isotope decays gradually. Each different ______ isotope has a characteristic rate of ______.

0-52 Bismuth, ${}_{83}Bi^{210}$, has a half-life of 5 days. Out of 200,000 atoms of ${}_{83}Bi^{210}$, after 10 days, or two ______, only ______ atoms of ${}_{83}Bi^{210}$ will remain.



o-9

glow in the dark
exposed to light

---

o-23

radioactive

---

o-37

radioactive decay
radioactive decay

---

o-51

50,000
25,000

---

m-1

positive
repulsion
nucleus

---

o-10

phosphorescent
glowed (emitted light)

---

o-24

radioactive
radioactive elements

---

o-38

radioactive
decay

---

o-52

half-lives
50,000

㉚

0-9 Becquerel studied many different substances to see which were phosphorescent, that is, to see which ones would ________ after being ________ ________.

0-23 Uranium ore contains many substances. Pierre and Marie Curie, students of Becquerel, attempted to isolate the ________ substance from the other substances in the ore.

0-37 The nuclear reaction that occurs when a nucleus spontaneously changes is called ________. Radium and polonium are elements that undergo ________ ________.

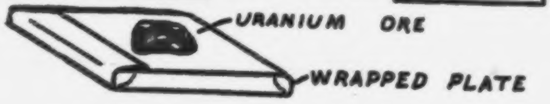
0-51 If 100,000 atoms of polonium remain after one half-life, ________ will remain after a second half-life and ________ after another half-life.

---

rN-2 Nuclear binding energy comes from some of the mass of the nucleus. Atomic ________ are held together by ________ ________.

㉛

O-11 Becquerel once accidentally placed some uranium ore on a photographic plate. The plate was wrapped in paper, so it would not be exposed by the ________ ore even if the ore was ________ and did emit ________.



O-25 The next radioactive element isolated by the Curies was radium. Like polonium, ________ spontaneously emits ________.

O-39 Radium, $_{88}Ra^{226}$, undergoes radioactive decay and becomes radon, $_{86}Rn^{222}$, but all the nuclei in a given amount of radium do not ________ at the same instant.

O-53 Most ________ isotopes that occur in nature have Z numbers above 82. $_{92}U^{238}$ for example, is a ________. Uranium, $_{92}U^{238}$, has a ________ of 4.5 billion years.

o-8

light
phosphorescent

---

o-22

elements
radiations

---

o-36

decay
radioactive decay (spontaneous nuclear reactions)

---

o-50

100,000
polonium (lead)
100,000 atoms of lead (polonium)

---

rn-2

nuclei
nuclear binding energy

③③

---

o-11

uranium
phosphorescent
light

---

o-25

radium
radiations (radioactivity)

---

o-39

decay (change)

---

o-53

radioactive
radioactive isotope
half-life

0-8 Phosphorescent materials glow in the dark after being exposed to ☐. Some clocks and watches have hands that contain ☐ materials.

0-22 Uranium ore contains uranium as well as isotopes of other ☐. Becquerel did not know which substance in the ore was emitting the ☐.

0-36 Radioactive ☐ is the change that occurs during a spontaneous nuclear reaction. Only radioactive isotopes ever undergo ☐.

0-50 Out of an original 200,000 atoms of polonium, ☐ will decay to lead during one half-life. After one half-life, there will be 100,000 atoms of ☐ and ☐ ☐.

rN-3 The energy holding a nucleus together is called ________ binding energy. This * ________________ ________ comes from some of the ______ of the nucleus.

㉟

0-12 Because the photographic plate was completely wrapped in paper, Becquerel did not expect the * ________________ to darken the * ________________.

0-26 Phosphorescent substances will expose photographic plates because they * ________________. Radioactive substances will likewise * ________________ because of the ________ they emit.

0-40 The nuclei in a given amount of a radioactive isotope decay a few at a time until every nucleus has ________ and become a nucleus of a * ________________.

0-54 Rate of radioactive ______ is measured in half-life, which is the amount of time it takes for ** ________________ ________________ ________________.

o-7

nuclear reactions
dark

36

---

o-21

radioactive

---

o-35

decay
decays (changes)
a different element

---

o-49

half
polonium
lead

---

(37)

rn-3

nuclear
nuclear binding energy
mass

---

o-12

uranium ore
photographic plate

---

o-26

glow in the dark
expose photographic plates (darken photographic plates)
radiations

---

o-40

decayed (changed)
different element

---

o-54

decay
half of an amount of a radioactive isotope to decay
(change to a different element)

0-7 Spontaneous ☐ were discovered in 1896 by Becquerel (Bek-ar-ell), a physicist who was studying phosphorescent substances. These are substances which glow in the ☐ after being exposed to light.

0-21 The spontaneous emission of radiations was named radioactivity and uranium ore was said to be radioactive. A ☐ substance spontaneously emits radiations.

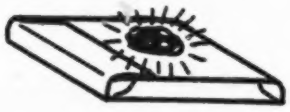
0-35 A spontaneous change in the structure of a nucleus is called radioactive ☐. A radioactive isotope spontaneously ☐ and becomes ☐.

0-49 The radioactive element polonium decays and changes to lead. During one half-life, ☐ of a given amount of the element ☐ will change into ☐.

---

rN-4 A nucleus always has ______ mass than the total mass of its separate nucleons; some ______ has been converted into ______.

0-13 Upon developing the photographic plate, Becquerel discovered that the uranium ore had darkened the plate. He assumed that the ______ was emitting rays which somehow passed through the paper.



0-27 Radioactivity occurs only in isotopes that have unstable nuclei. Those nuclei which can spontaneously change through radioactivity are called ______ nuclei.

0-41 Rate of decay is measured in half-life. An isotope that has a rapid rate of decay has a shorter ______ than an isotope that decays slowly.

0-55 Radioactive decay is a result of ______ nuclear reactions. Only radioactive isotopes which have ______ nuclei ever undergo ______.

40

o-6

spontaneous

o-20

phosphorescent

uranium

o-34

decay

radioactive decay (spontaneous change)

o-48

25,000

rn-4

less

mass

nuclear binding energy

(41)

---

o-13

uranium ore

---

o-27

unstable

---

o-41

half-life

---

o-55

spontaneous

unstable

radioactive decay (spontaneous nuclear reactions)

0-6 A nuclear change that occurs without any outside cause is called a ________ nuclear reaction.

0-20 Becquerel was studying the light emitted from ________ substances when he discovered the kind of radiations emitted by ________ ore.

0-34 A spontaneous change in a nucleus is called radioactive decay. Unstable nuclei change or ________ and become different nuclei. Only radioactive isotopes undergo ________ ________.

0-48 After one half-life, only 50,000 of the original 100,000 atoms will remain. After another half-life, only ________ of those 50,000 atoms will remain.

PN-5 The mass of every nucleus is less than the total mass of its separate nucleons because ____________________ ____________________.

0-14 Becquerel then discovered that uranium ore did not have to be exposed to ________ before being able to darken a ____________________.

0-28 Spontaneous nuclear reactions occur only in radioactive isotopes. $_{92}U^{238}$ has ________ nuclei and is a ________ ________ of the element uranium.

0-42 The half-life of a ____________ isotope is the time required for half of a given number of nuclei of that isotope to ______.

0-56 An isotope which has an unstable nucleus is ____________, which means that it will ________ ____________________.

o-5

spontaneously

o-19

radiations

nuclear reactions

o-33

unstable

o-47

50,000

rn-5

some of the mass has been converted to nuclear binding energy

45

---

o-14

light

photographic plate

---

o-28

unstable

radioactive isotope

---

o-42

radioactive

decay

---

o-56

radioactive

spontaneously change (decay) and become a nucleus of a different element (and emit radiations)

O-5 Sometimes nuclear changes occur spontaneously, that is, without being bombarded by particles. A nuclear reaction without any outside cause is said to occur __________.

O-19 The nucleus was discovered about fifteen years after Becquerel discovered that uranium ore emitted __________. We know now that these radiations are produced by spontaneous __________.

O-33 The nuclei of most isotopes are stable. The nuclei of radioactive isotopes are __________.

O-47 If the half-life of an isotope is one hour, and at one o'clock there are 100,000 atoms of that isotope; then at two o'clock there will be __________ atoms of that isotope remaining.

0-1 A nucleus can be changed to a different element by bombarding it with particles so as to cause a *__________ __________.

㊼

0-15 Becquerel found that uranium ore __________ photographic plates, but he also discovered uranium ore did not emit visible __________ so the ore was not __________.

0-29 Radioactive isotopes are those having unstable __________ which undergo __________ nuclear reactions and emit __________.

0-43 The *__________ of a radioactive isotope is the time it takes for half of a given number of nuclei to decay and **__________.

END OF UNIT

o-4

nuclei (atoms) were bombarded by particles

(48)

o-18

radiation

o-32

spontaneously change to a different element (emit radiations)

o-46

half-life
half
decay

o-1

nuclear reaction

---

o-15

exposed (darkened)
light
phosphorescent

---

o-29

nuclei
spontaneous
radiations

---

o-43

half-life
change to a different element (become nuclei of a different element)

0-4 The nuclear reactions you have learned about so far occurred when ________ ________.

0-18 The uranium ore emitted radiation independently of any external conditions. Nothing affected the amount of ________ emitted by the ore.

0-32 The nuclei of most elements found in nature are not radioactive, that is, they never ________ ________.

0-46 The ________ of $_{92}U^{238}$ is 4.5 billion years. This means that it takes 4.5 billion years for ________ of a given amount of $_{92}U^{238}$ to ________.

O-2 A change in the structure of the ________ of an atom is called a ________ reaction.

(51)

O-16 Uranium ore exposed photographic plates even though it ** ________________. Something else about uranium ore was darkening the plates.

O-30 Radioactive isotopes have ________ nuclei which spontaneously change to a different element. Isotopes with stable nuclei do not spontaneously ________ and become ** ________________.

O-44 As shown in the table, during one half-life, half of a given number of nuclei will ________. During the next half-life, ________ of the remaining nuclei will ________.

originally	100,000 nuclei
one half-life	50,000 nuclei
second half-life	25,000 nuclei
third half-life	12,500 nuclei

o-3

change in the structure of a nucleus

(52)

o-17

radiation

o-31

isotopes
element

o-45

half-life

o-2

nucleus
nuclear

o-16

did not emit visible light (was not phosphorescent)

o-30

unstable
change
(nuclei of) a different element

o-44

decay
half
decay

(54)

0-3 The nuclear reactions you have learned about were caused by bombarding nuclei with particles. A nuclear reaction always results in a ** ______________________ ______________.

0-17 Radiation is the word physicists use to describe emissions from a substance. Since the uranium ore exposed plates, it must be emitting some sort of ______________.

0-31 As you will soon learn, radioactive isotopes never become new ______________ of the same element. Instead, they always become isotopes of some other ______________.

0-45 ${}_{92}U^{238}$ is a radioactive isotope of uranium. ${}_{92}U^{238}$ has a * ______________ of 4.5 billion years.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 0-3

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 0-17

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 0-31

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 0-45

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER

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UNIT P - Radioactive Radiations
plus review of Unit O

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER P-5

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER P-19

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER P-33

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER P-47

END OF UNIT

START HERE

P-1 A nucleus can be changed to a nucleus of a different element by bombarding it with particles so as to cause a ________ ________.

(59)

P-5 The least penetrating ________ are named alpha rays. The next, in order of ________ power, are called beta (bay-ta) rays, and the most penetrating are called gamma ________.

P-19 The ________ charged beta particles were found to be ordinary electrons. Thus, both ________ rays and ________ rays consist of charged particles.

P-33 Unstable nuclei contain excess or surplus energy. A nucleus is ________ if it contains excess ________.

P-47 Photons can, under certain conditions, ionize atoms by knocking electrons loose. This suggests that photons have ________ even though they ________ have mass.

p-4

radiations
penetrate

09

p-18

radioactive
radioactive isotopes (radioactive substances)

p-32

alpha
beta
gamma ray

p-46

momentum
velocity

ro-1

nuclear reaction

(61)

---

p-5

radiations
penetrating
rays

---

p-19

negatively
alpha (beta)
beta (alpha)

---

p-33

unstable
energy

---

p-47

momentum
do not

P-4 The three different types of radiations all penetrate matter, but each type of ______ does not ______ an equal amount.

(62)

P-18 Alpha particles are one of the radiations emitted by some ______ substances. Earlier you learned how alpha particles, which are emitted by ______, were used in scattering experiments.

P-32 An unstable nucleus can emit either an ______ or a ______ particle, but not both. When either occurs, a ______ ______ can also be emitted.

P-46 In general, objects which can move other objects have ______, which means they have both mass and ______.

---

rO-2 Some nuclei will undergo spontaneous nuclear decay. These are called [   ] nuclei. Radium nuclei, for example, are [*   ] and undergo [   ] nuclear decay.

(63)

P-6 Gamma rays are more penetrating than beta rays, and, in turn, alpha rays are less [   ] than either [**   ].

P-20 Radioactive substances can emit two kinds of rays which consist of charged [   ]. These are [**   ] [   ].

P-34 A gamma ray is a wave of energy. When an unstable nucleus [   ] a gamma ray, there is a decrease in the amount of [   ] in the nucleus.

P-48 Photons can ionize atoms, which indicates that they have [   ] even though they do not have any [   ].

p-3

3

through matter

---

p-17

alpha particles

---

p-31

element

change the nucleus to a different element

---

p-45

momentum

---

ro-2

unstable
unstable nuclei
spontaneous

(65)

---

p-6

penetrating
beta rays or gamma rays

---

p-20

particles
alpha and beta rays (alpha particles and electrons)

---

p-34

emits
energy

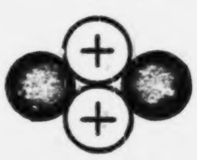
---

p-48

momentum
mass

P-3 One of the first discoveries about the ☐ kinds of radiations from radioactive isotopes was that they differ in penetrating power, which means how easily the radiations pass ☐ ☐.

P-17 By determining their mass, it was found that alpha rays were nuclei of helium, ${}_{2}\mathrm{He}^{4}$. The particles which make up "alpha rays" are now known as ☐ ☐.



P-31 Gamma emission does not change a nucleus to a different ☐, but the emission of either an alpha or beta particle does ☐.

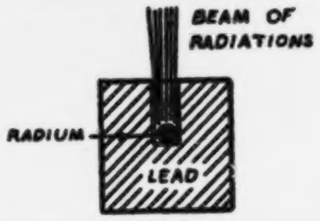
P-45 Objects that have mass and velocity have momentum, which is the ability to move other objects. An object that has both mass and velocity has ☐.

---

r0-3 Radioactive isotopes undergo spontaneous decay, which means they change to a ________ element and emit ________ without being bombarded by other particles.

(67)

P-7 Alpha, ________, and ________ radiations will form a beam if a ________ substance such as radium is placed at the bottom of a hole made in a block of lead shielding.



P-21 Alpha rays consist of ________. Beta rays consist of negatively charged particles called ________.

P-35 The emission of a gamma ray reduces the amount of ________ in an ________.

P-49 The momentum of a photon depends on its energy. Gamma rays are high energy ________, and thus have greater ________ than radio waves, which are lower energy photons.

p-2

radioactive
3
emitted

(89)

p-16

alpha
beta rays

p-30

gamma
alpha (beta)
beta (alpha)

p-44

mass
velocity

ro-3

different
radiations (particles)

p-7

beta (gamma)
gamma (beta)
radioactive

p-21

alpha particles (helium nuclei)
electrons

p-35

energy
unstable nucleus

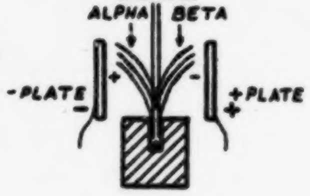
p-49

photons
momentum

P-2 There are many radioactive elements found in nature. As these ☐ substances decay, ☐ # different types of radiations are ☐.

(OL)

P-16 The positively charged rays were found to be the least penetrating radiations, the ☐ rays. The negatively charged rays were the ☐.



P-30 Gamma emission occurs only immediately after an alpha or beta decay has occurred. A nucleus can emit a ☐ ray along with an ☐ or ☐ particle.

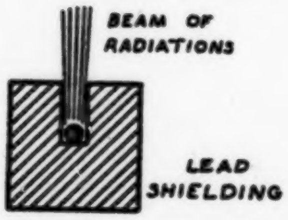
P-44 A photon has velocity, but is not matter and has no ☐. All photons have the same ☐, which is the speed of light, approximately 186,000 miles per second.

END OF UNIT

P0-4 Radioactive isotopes have ☐ nuclei that spontaneously change or ☐ and become nuclei of different ☐ .

(71)

P-8 The beam of radiations streaming from the hole in the lead block will penetrate or pass through matter, but the alpha rays in the beam are not as ☐ ☐.



P-22 Nuclei contain protons and neutrons, but never contain ☐. However, the radiations emitted by radioactive substances do include beta rays which are a stream of ☐.

P-36 Gamma rays are a form of radiant energy. X-rays, light waves, and radio waves are also forms of ☐ ☐.

P-50 Blue light has more energy than red light. Therefore, photons of blue light have greater ☐ than red light photons.

p-1

radioactive
radiations

72

---

p-15

gamma

---

p-29

mass
emit
charge nor mass

---

p-43

particle-like bundles of (radiant) energy
mass or charge

---

p-57

energy
gamma ray

ro-4

unstable
decay
elements

p-8

penetrating as beta or gamma rays

p-22

electrons
electrons

p-36

radiant energy

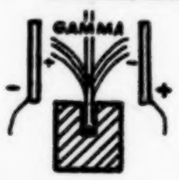
p-50

momentum (energy)

P-1 All of the radiations emitted by ______ isotopes are not alike. There are three different kinds of ______ emitted by decaying nuclei.

(74)

P-15 The rays that were not deflected were found to be the most penetrating radiations, the ______ rays.



P-29 Unstable nuclei can emit alpha or beta particles, which are charged and have ______. Unstable nuclei can also ______ gamma rays, which have neither * ______.

P-43 Photons are ** ______ ______. They are not matter; they have no * ______ ______.

P-57 Gamma rays are energy. The amount of excess ______ in an unstable nucleus can be reduced by the emission of a * ______.

rO-5 Becquerel discovered that some substances are ________, which means they emit radiations. Substances which emit ________ have ________ nuclei.

(75)

P-9 To find out what radiations consist of, a radiation beam was passed through an electric field. Radiations consisting of charged ________ would be ________ by the electric field.

P-23 Beta particles can result from spontaneous nuclear ________ even though normally there are ________ electrons in the nucleus. Beta particles can be produced by ________ ________.

P-37 Radiant ________ is usually described as a wave. Light rays travel in waves. Radio messages, X-rays, and gamma rays are other forms of ________ and also ________ ________.

P-51 High energy photons have greater ________ than low energy photons. Both high and low energy photons travel at the same ________.

ro-10

nuclei
radioactive isotope
radiations

9L

p-14

penetrating

p-28

alpha particles (rays), beta particles (rays) (electrons) and gamma rays

p-42

photons
energy
mass

p-56

radiant energy
energy (momentum)

ro-5

radioactive
radiations
unstable

p-9

particles
deflected (bent)

p-23

decay (reactions)
no
(spontaneous) nuclear reactions (radioactive decay)

p-37

energy
radiant energy
travel in waves (as a wave)

p-51

momentum (energy)
velocity (speed)

P-10 Atoms of radium, $_{88}Ra^{226}$, have unstable ________. $_{88}Ra^{226}$ is a •________ which emits ________ as it decays and becomes radon, $_{86}Rn^{222}$.

P-14 Because the three kinds of radiations each have different ________ powers, it was possible to determine the charge for each kind of ray.

P-28 The three types of radiation from radioactive decay are ••________, ________, ________.

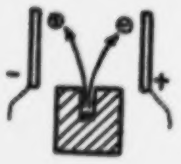
P-42 Gamma rays consist of ________, which are particle-like bundles of radiant ________. Gamma ray photons, like light and X-ray photons, have neither charge nor ________.

P-56 Light rays travel in waves and consist of photons, which are particle-like bundles of •________. Gamma rays consist of very high ________ photons.

(79)

rO-6 Radioactive isotopes decay spontaneously. $_{92}U^{238}$ is a ________________ of the element ________. It changes, or ________, and becomes an isotope of a ________________.

P-10 If radiations consist of charged particles, positive particles would be deflected toward the ________ plate while negative particles would be ________________.



P-24 The most penetrating of the three radiations, the ________ rays, were found to have no mass. They are similar to light waves which also have ________.

P-38 A stone dropped into a pool of water produces ________ that radiate out from the spot where the stone strikes the water. Radiant energy also travels in ________.

P-52 Photons have ________, which means that they are similar to particles having both ________ and velocity.

ro-9

1/8

08

p-13

penetrating

p-27

alpha
electrons
gamma

p-41

photons
charge

p-55

radiant energy
mass

ro-6

radioactive isotope
uranium
decays
different element

p-10

negative
deflected toward the positive plate

p-24

gamma
no mass

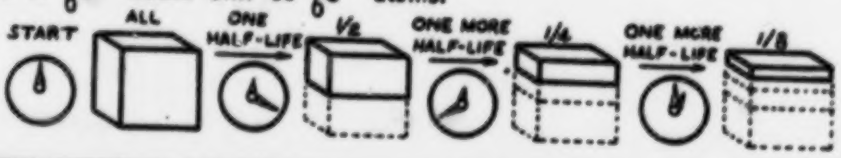
p-38

waves
waves

p-52

momentum
mass

r0-9 Carbon $_6C^{11}$ is a radioactive isotope with a half-life of 20 minutes. After one hour, only ☐ of the atoms in an object made of $_6C^{11}$ would still be $_6C^{11}$ atoms.



P-13 Alpha, beta and gamma rays were affected differently by an electric field, and each has a different ☐ power, that is, ability to pass through matter.

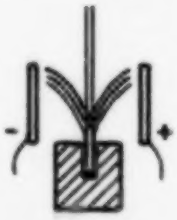
P-27 During radioactive decay, three kinds of radiation are emitted: ☐ particles; beta rays, which consist of a stream of ☐; and ☐ rays.

P-41 Radiant energy can be described as a stream of particle-like bundles of energy called ☐, which have no electrical ☐ and no mass.

P-55 Photons are bundles of ☐ which act like particles and have momentum even though they have no ☐.

rO-7 Radioactive isotopes [ ] at different rates, as measured by their half-lives. During one [*], half of a given number of atomic [ ] will decay.

P-11 As shown in the figure, when the electric field was turned on, some rays were deflected toward the positive plate, some toward the negative plate, and some were [**].



P-25 Gamma rays have neither [ ] nor an electrical [ ].

P-39 Light rays are waves of energy but they can also be described as a stream of particles called photons (foe-tahns). X-rays and all forms of [*] consist of [ ].

P-53 Because photons can knock electrons from atoms, producing positive [ ], we know that photons have [ ].

ro-8

radioactive isotope

required for half of a given number of nuclei to decay (and become a different element)

---

p-12

positively

negatively charged

---

p-26

do not consist of charged particles (have neither mass nor charge)

---

p-40

photon

mass

matter

---

p-54

ionize

momentum

ro-7

decay
half-life
nuclei

(85)

---

p-11

not deflected at all

---

p-25

mass
charge

---

p-39

radiant energy
photons

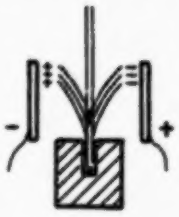
---

p-53

ions
momentum (energy)

rO-8 The half-life of a •________ is the length of time ••________________________ ________________.

P-12 The rays deflected toward the negative plate were ________ charged and the rays deflected toward the positive plate were •________________.



P-26 Although alpha rays and beta rays both consist of charged particles, gamma rays ••________________________ ________________.

P-40 A photon is a particle-like bundle of radiant energy that has no mass. Because a ________ has no ________, we know it does not consist of ________.

P-54 Gamma rays can ________ atoms by removing electrons, because gamma ray photons have ________.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER O-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER P-12

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER P-26

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER P-40

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER P-54

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UNIT Q - Alpha and Beta Decay

plus review of Unit P

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Q-5

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Q-19

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Q-33

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Q-47

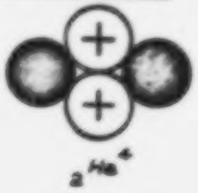
END OF UNIT

START HERE

rP-1 As they decay, nuclei of ☐ isotopes emit radiations. Three different kinds of ☐ are emitted.

Q-5 Gamma rays produce relatively few ions and are neither attracted nor repelled by charged particles because a gamma ray has no ☐ or ☐.

Q-19 Alpha decay is the emission of an ☐ ☐ from an ☐ nucleus.



Q-33 A change in the A number means there is a change in the number of ☐ and hence a change in the amount of ☐ in the nucleus.

Q-47 In beta$^-$ decay, an electron is emitted, but you know that there are no ☐ in the ☐ of any atom.

q-4

alpha particle
gamma ray

---

q-18

some nucleons (2 protons and 2 neutrons)

---

q-32

different element
atomic
mass

---

q-46

beta plus (beta $^{+}$)
beta minus (beta $^{-}$)

rp-1

radioactive
radiations

---

q-5

charge (mass)
mass (charge)

---

q-19

alpha particle
unstable (radioactive)

---

q-33

nucleons
mass

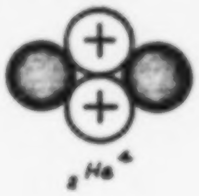
---

q-47

electrons
nucleus

Q-4 An alpha particle will produce thousands of times as many ions as a gamma ray. Because it is charged, an ________ produces more ions than a ________.

Q-18 When an alpha particle is emitted, the number of nucleons in a nucleus is changed because an alpha particle consists of ________.



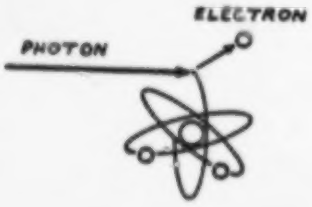
Q-32 A nucleus which undergoes alpha decay becomes a nucleus of a ________. The new nucleus has a different Z, or ________ number and a different A, or ________ number.

Q-46 There are two different kinds of beta decay, ________ and ________. Each produces a different kind of change in the nucleus.

rP-2 The radiations emitted during radioactive decay differ in penetrating power, which means how easily the radiations pass ________ ________. They also differ in their electrical ________.

(95)

Q-6 A gamma ray has no charge and therefore is neither repelled by nor ________ charged particles. To produce an ion, a gamma ray must hit an ________ head-on.



Q-20 When a nucleus emits an alpha particle it loses a total of ____ nucleons, of which ____ are protons and ________ ________.

Q-34 A change in the Z number means there is a change in the number of ________ in the nucleus and hence a change in the electrical ________ of the nucleus.

Q-48 The electron emitted in beta$^-$ decay does ________ originally exist in the nucleus; instead, it is created when ________ ________ decay occurs.

q-3

ionize atoms (knock electrons loose)

---

q-17

nucleons (particles) (protons or neutrons)
energy

---

q-31

2
4

---

q-45

beta$^-$
charges in the nucleus

rp-2

through matter
charge

⑨⑦

q-6

attracted to
electron

q-20

4
2
2 are neutrons

q-34

protons
charge

q-48

not
beta minus (beta$^-$)

Q-3 Because they have momentum, gamma rays can ionize atoms by knocking electrons loose. Alpha and beta particles can also ____________.

Q-17 Gamma emission does not change the number of ________ in a nucleus but does reduce the amount of excess ________ in an unstable nucleus.

Q-31 In alpha decay, the nucleus loses both protons and neutrons. Thus, it loses ____ of its positive charges and approximately ____ of its amu.

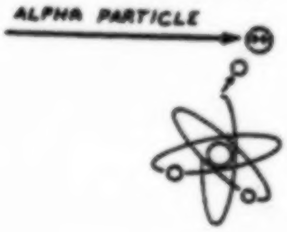
Q-45 There are two kinds of beta decay, beta plus (+) and beta minus (−). Both beta^{+} and ________ decay change the number of ____________.

---

rP-3 The least penetrating radiations are $_2He^4$ nuclei, called ________ particles. The most penetrating are the ________ rays. In between are the ________ particles.

(99)

Q-7 An alpha particle can ionize atoms without actually hitting them because of the force of ________ between particles with unlike charges.



Q-21 Radium, $_{88}Ra^{226}$, decays by emitting an alpha particle. This is called alpha decay. When $_{88}Ra^{226}$ undergoes ________ ________, it loses ________ positive charges.

Q-35 An alpha particle has both charge and ________. Thus, during alpha emission, there is a change in both the ________ ________ of the nucleus.

Q-49 In both beta$^-$ and ________ decay, a particle is ________. In beta$^-$ decay, this particle is a ________ charged electron.

q-2

gamma ray
energy

001

q-16

gamma rays
alpha rays or beta rays (alpha particles or electrons)

q-30

$_{88}Ra^{228}$

q-44

charge
mass of the nucleus (number of nucleons in the nucleus)

rp-3

alpha
gamma
beta

---

q-7

attraction

---

q-21

alpha decay (radioactive decay)
2

---

q-35

mass
charge and mass

---

q-49

beta^{+}
emitted
negatively

Q-2 The number of nucleons in an unstable nucleus does not change when a $\boxed{*}$ is emitted, but its amount of excess $\boxed{}$ is reduced.

(201)

Q-16 Because they are very penetrating, $\boxed{*}$ $\boxed{}$ can be detected farther from a source of radioactivity than either $\boxed{**}$.

Q-30 Many radioactive nuclei decay by alpha emission; for example, thorium, symbol ${}_{90}Th^{232}$, becomes an isotope of radium, Ra, in the reaction.

$$ {}_{90}Th^{232} \longrightarrow \boxed{\$} + {}_{2}He^{4} $$

Q-44 Physicists have discovered two kinds of beta decay. Both kinds result in a change in the $\boxed{}$ of a nucleus, but neither affect the $\boxed{**}$.

END OF UNIT

rP-4 Alpha particles are ☐ charged. Beta particles have a ☐ charge. Gamma rays do not have a ☐, nor do they have any ☐.

(103)

Q-8 Alpha rays are quickly stopped as they pass through matter because they are ☐ particles; they do ☐ penetrate much matter before they are finally ☐.

Q-22 When radium, $_{88}Ra^{226}$, undergoes alpha decay, it loses a total of ☐ # nucleons. The number of positive charges in the nucleus changes from ☐ # to ☐ #.

Q-36 A nucleus changes to a new element when it gains or loses charges. Alpha decay ☐ the number of charges in a nucleus, therefore, a ☐ * results.

Q-50 During beta$^-$ decay, a ☐ charged particle is emitted. In beta$^+$ decay, a particle is also ☐, but in this case, it is a ☐ charged particle.

q-1

gamma
beta decay

q-15

gamma rays
penetrating

q-29

energy (photons)
2 protons and 2 neutrons (some of its mass)
element (nucleus)

q-43

mass
does change

q-57

positrons
beta$^-$

rp-4

positive
negative
charge
mass

---

q-8

charged
not
stopped

---

q-22

4
88
86

---

q-36

reduces (lowers, changes)
new element (new nucleus)

---

q-50

negatively
emitted
positively

Q-1 There are three kinds of radioactive decay. No particles are emitted in ______ decay, but particles are emitted in alpha decay and ______.

Q-15 All radiations are eventually stopped by matter, but ______ are far more ______ than either alpha or beta particles.

Q-29 When gamma emission occurs, the nucleus emits only ______. When alpha decay occurs, the nucleus loses ______ ______ and becomes a new ______.

Q-43 Beta decay does not reduce the number of nucleons. Thus, in beta decay the ______ number does not change, although the atomic number ______.

Q-57 Neither electrons nor ______ exist inside nuclei; they are created when a nucleus undergoes beta^{+} or ______ decay.

rP-5 Three kinds of radiations are emitted during radioactive [ ]. These are [**] [ ].

(107)

Q-9 An alpha particle is slowed each time it pulls an [ ] loose from an atom. Even so, an alpha particle can produce many ions before [**].

Q-23 The nucleus of $_{88}Ra^{226}$ contains [#] nucleons, of which 88 are [ ]. When radium emits an alpha particle, the total number of nucleons changes from [#] to [#].

Q-37 Beta decay, like alpha decay, involves a change in the number of charges in a [ ], and therefore, a change to a different [ ].

Q-51 In $beta^-$ decay, an electron, that is, a [*] [ ] particle is emitted. In $beta^+$ decay, a [**] [ ].

rp-10

energy
charge nor mass
penetrating

---

q-14

penetrating
gamma

---

q-28

alpha decay
$_{82}Pb^{206}$

---

q-42

alpha decay
beta decay

---

q-56

electron or positron
small

rp-5

decay

alpha rays, beta rays, and gamma rays (alpha particles, electrons, and gamma rays)

---

q-9

electron

being stopped (completely)

---

q-23

226

protons

226

222

---

q-37

nucleus

element

---

q-51

negatively charged

positively charged particle is emitted

rP-10 Gamma rays consist of bundles of [ ] called photons. They have neither [•] and, compared with other radiations, they are very [ ].

011

Q-14 An alpha particle can travel only an inch or two in air. Therefore, alpha particles are not very [ ] compared to [ ] rays.

Q-28 Both the Z and A number of a nucleus change whenever [•] occurs. For example, polonium, ${}_{84}\mathrm{Po}^{210}$, becomes lead, symbol Pb, plus ${}_{2}\mathrm{He}^{4}$, or ${}_{84}\mathrm{Po}^{210} \longrightarrow$ [$] $+ {}_{2}\mathrm{He}^{4}$.

Q-42 Both Z and A numbers change as a result of [•], but only Z changes as a result of [•].

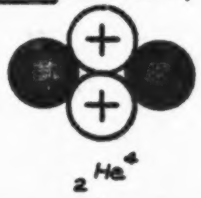
Q-56 Compared to the mass of either protons or neutrons, the mass of either an [•] is very [ ].

rP-6 An unstable nucleus can emit either an alpha or a beta particle but ☐ both. Alpha particles are ☐ nuclei; beta particles are ☐.

(111)

Q-10 Because it is charged, an alpha particle produces many ☐ and thus loses ☐ quickly.

Q-24 When a nucleus alpha decays, its Z or ☐ number is reduced by # ☐ and its A, or ☐ number is reduced by # ☐.



Q-38 When beta decay occurs, the nucleus changes to a ☐ because the number of ☐ in the nucleus is changed.

Q-52 Although the particle emitted in beta$^+$ decay is ☐ charged, it is ☐ a proton.

rp-9

mass
photons
momentum

q-13

penetrating

q-27

2
4

q-41

changes
does not change (remains the same)

q-55

positrons
mass
charge

rp-6

not
helium $({}_{2}\mathrm{He}^{4})$
electrons

q-10

ions
velocity (energy) (momentum)

q-24

atomic
2
mass
4

q-38

new element
charges (protons)

q-52

positively
not

(#11)

rP-9 Photons have momentum even though they have no ________. Gamma rays consist of high energy ____________ which are able to ionize atoms and thus have considerable ____________.

Q-13 Gamma rays travel many feet in air. Because they have no charge, gamma rays are very ________________.

Q-27 When polonium alpha decays, it becomes lead. Because an alpha particle is emitted, you know polonium has #______ more protons than lead, and has approximately #______ amu greater mass.

Q-4i In beta decay, a nucleus does not emit nucleons, but the nuclear charge does change. This means that the Z number ____________ but the A number ________________.

Q-55 Electrons and __________ have the same amount of ________ but are opposite in ________.

rP-7 Unstable nuclei contain excess energy. An [ ] nucleus loses its [*] by emitting a [ ] ray, which is a wave of radiant energy.

(115)

Q-II A gamma ray is usually stopped completely when it hits an electron. One gamma ray usually produces only [#] ion before it is completely [ ].

Q-25 Radium, ${}_{88}Ra^{226}$, undergoes alpha decay and becomes radon, symbol Rn. The Z number of radon is [#], the A number is [#]. The complete symbol is [$].

Q-39 During beta decay, the electrical [ ] of the nucleus changes, but there are as many nucleons after the reaction as there were [*].

Q-53 In beta^{+} decay, there is a change in the [ ] of the nucleus, but [ ] in the number of nucleons.

rp-8

energy
photon

911

---

q-12

electron

---

q-26

2
is reduced by 4

---

q-40

mass (A)
same

---

q-54

positron
charge

rp-7

unstable
excess energy
gamma

(117)

q-11

I
stopped

q-25

86
222
$_{86}Rn^{222}$

q-39

charge
before the reaction

q-53

charge
not

rP-8 Gamma rays travel in waves and consist of bundles of ________ called photons. A ________ has no mass.

Q-12 A gamma ray can penetrate a considerable amount of matter before being stopped because the chance of a head-on collision with an ________ is very small.

Q-26 When a nucleus alpha decays, its Z number is reduced by ________ and its A number ________.

$${}_{88}Ra^{226} \longrightarrow {}_{86}Rn^{222} + {}_{2}He^{4}$$

Q-40 In beta decay, there is no change in the total number of nucleons. Therefore, the ________ number of the nucleus remains the ________.

Q-54 The positively charged particle emitted in beta^{+} decay is called a positron. This particle, the ________, has the same mass as an electron, but an opposite electrical ________.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rP-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Q-12

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Q-26

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Q-40

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Q-54

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(121)

UNIT R - Beta Decay Reactions

plus review of Unit Q

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER R-1

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER R-15

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER R-29

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER R-43

END OF UNIT

START HERE

rQ-1 There are three kinds of [ ] decay. No particles are emitted during [ ] ray emission, but particles are emitted during both [ ] decay and [*].

(123)

R-1 When a nucleus undergoes gamma decay, only [ ] is emitted by the unstable nucleus, and there is no change in either the [*] of the nucleus.

R-15 During either beta$^-$ or beta$^+$ decay, a new [ ] is created and emitted from the nucleus. Neither electrons nor [ ] ever exist inside the nucleus.

R-29 The symbol $_{-1}e^0$ represents an electron. Because its mass is so [ ] compared to nucleons, an electron has a mass number of [$].

electron: $Z = -1$
$A = 0$

R-43 Beta$^-$ decay can occur naturally, but beta$^+$ decay is never found in natural radioactive isotopes. Both beta$^-$ and beta$^+$ decay can occur in man-made [*].

(124)

rq-14

positrons
nucleus
beta

---

r-14

neutron
proton
electron

---

r-28

90
91
A

---

r-42

charge (mass)
mass (charge)
beta

---

rq-1

radioactive
gamma
alpha (beta)
beta decay (alpha decay)

r-1

energy
A or Z numbers (mass or atomic numbers) (number of protons or neutrons)

r-15

particle
positrons

r-29

small
0

r-43

radioactive isotopes

rQ-14 Neither electrons nor ☐ ever exist in the ☐. These particles are formed during ☐ decay.

R-14 During beta⁻ decay, a ☐ changes into a ☐ and a negatively charged particle, the ☐, is emitted.

R-28 Thorium, ${}_{90}Th^{234}$, beta⁻ decays and becomes proactinium, symbol Pa. The Z number of the nucleus changes from #☐ to #☐; but there is no change in the $☐ number.

R-42 Since neutrinos have no ☐ and no ☐, they are usually left out of beta decay equations, but they are always emitted during a ☐ decay.

(127)

rQ-2 Because they have both charge and ☐, alpha and beta particles are stopped quickly by matter, which means they are not very ☐.

R-2 During alpha decay, the nucleus emits a particle that consists of ☐. Alpha decay reduces both the mass and the electrical ☐ of the nucleus.

alpha particle

R-16 Careful experiments have indicated that during beta decay, more energy is emitted from the nucleus than is taken up by either the electron or the ☐.

R-30 Positrons and electrons have the same mass but ☐ charges. The symbol $_{-1}e^{0}$ is used to represent an electron and $_{+1}e^{0}$ to represent a ☐.

electron: $Z = -1$, $A = 0$

positron: $Z = +1$, $A = 0$

R-44 Beta^{+} decay occurs only in man-made radioactive isotopes. $_{11}Na^{22}$, for example, is man-made, and undergoes ☐ and becomes $_{10}Ne^{22}$.

rq-13

negatively
goes up (is increased)
positively
goes down (is decreased)

---

r-13

proton
neutron
positron

---

r-27

different (new)

---

r-41

energy
neutrino

rq-2

mass
penetrating

---

r-2

two protons and two neutrons (a $_2He^4$ nucleus)
(4 nucleons)
charge

---

r-16

positron

---

r-30

opposite
positron

---

r-44

beta$^+$ decay

(130)

rQ-13 In beta$^-$ decay the particle emitted is __________ charged, so the Z number __________. In beta$^+$ decay the particle emitted is __________ charged so the Z number __________ __________.

R-13 During beta$^+$ decay, a __________ changes into a __________ and a positively charged particle called a __________ is emitted.

R-27 When the number of protons in a nucleus is changed, the nucleus changes to a __________ element.

R-41 During both kinds of beta decay, a bundle of __________ called a __________ is always emitted along with either an electron or positron.

---

rQ-3 Gamma emission reduces the amount of excess ________ in a nucleus but does not reduce the number of ______________ in it.

(131)

R-3 During beta decay, there is no change in the ________ number of the nucleus, but the nucleus does gain or lose a positive ________.

R-17 It was discovered that the extra energy emitted during beta decay is in the form of a bundle of ________ named the neutrino (new-tree-no).

R-31 In writing equations for beta decay, $_{-1}e^{0}$ means an electron and $_{+1}e^{0}$ means a ________. The sign of the Z number at the left indicates the ________ of the particle.

R-45 Whenever the number of positive charges in a nucleus changes, a new ________ is produced. Both alpha and beta decay involve a change in the ______________________.

rq-12

positive
electron
loses

---

r-12

positive
neutrons
proton

---

r-26

a neutron becomes a proton (in beta⁻ decay) (there is an increase in the number of protons) (the number of positive charges increases)

---

r-40

$_{25}Mn^{55}$
$_{-1}e^{0}$

---

rq-3

energy
nucleons (particles)

⑬3

---

r-3

mass
charge

---

r-17

energy

---

r-31

positron
charge

---

r-45

element
numbers of positive charges (protons)

rQ-12 During beta⁻ decay, a nucleus gains a ______ charge as it emits an ______. During beta+ decay, a nucleus ______ a positive charge.

R-12 When beta⁻ decay occurs, the nucleus gains a ______ charge. One of the ______ in the nucleus turns into a ______, and an electron is emitted.

neutron ⟶ proton + electron

R-26 The Z number always increases in beta⁻ decay, because •• ______.

R-40 An example of beta⁻ decay is when chromium, $_{24}Cr^{55}$ changes into manganese, $_{25}Mn^{55}$. The reaction equation is:

$$_{24}Cr^{55} \longrightarrow \boxed{\$} + \boxed{\$}.$$

END OF UNIT

rQ-4 When an alpha particle is emitted by a nucleus, both the Z, or ☐ number and the A, or ☐* of the nucleus are ☐.

(135)

R-4 A nucleus always has a positive electrical ☐. If the number of protons in a nucleus changes, the amount of positive ☐ changes.

R-18 A neutrino is a bundle of ☐ emitted during beta decay. Like a photon, a ☐ has no charge and no ☐

R-32 The mass number of a nucleus does not change in beta decay since no ☐ are emitted. Since the number of charges does change, the ☐ number changes.

R-46 Alpha decay results in a change in both the number of positive charges and number of nucleons, while beta decay results only in a ☐**.

rq-11

beta^{-} (beta plus)
beta^{+} (beta minus)

---

r-11

beta^{+}
protons
neutron
mass number (A number)

---

r-25

protons
16
neutrons
16

---

r-39

is increased (goes up) (changes)
is not changed (remains the same)

---

r-53

electrons and positrons
mass

rq-4

atomic
mass number
reduced (changed)

(137)

r-4

charge
charge

r-18

energy
neutrino
mass

r-32

nucleons
atomic (Z)

r-46

change in number of positive charges

rQ-11 The atomic number changes but the mass number of a nucleus does not change during either ______ or ______ decay.

R-11 When a positron is emitted during ______ decay, one of the ______ in the nucleus becomes a ______. This changes the atom's atomic number but not its ______.

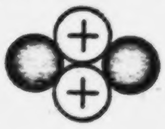
R-25 $_{15}P^{32}$ has 15 protons and 17 neutrons. Beta$^-$ decay will increase the number of ______ to ______ and reduce the number of ______ to ______.

R-39 In beta$^-$ decay the Z number of the original nucleus ______. The A number ______.

R-53 Two kinds of charged particles are emitted in beta decay. These particles, ______, each have the same ______, about 1/1840 amu.

(139)

rQ-5 An alpha particle consists of two protons and °__________ __________. Thus, when alpha decay occurs, the Z number of the nucleus drops by #______ and the A number °__________ __________.



R-5 During either beta⁺ or beta⁻ decay, the total number of __________ in the nucleus remains the same, but the number of positive ________ in the nucleus changes.

R-19 Photons and neutrinos are bundles of __________ that have neither °____________________.

R-33 The symbol ${}_{+1}e^{0}$ indicates that the Z number of the original nucleus is reduced by #____, but the A number is °____________________.

R-47 A nucleus consists of only two kinds of particles. These are **____________________.

rq-10

positron
charge

r-10

atomic number (nuclear charge)

r-24

electron
neutrons
proton
16

r-38

$_{23}V^{49}$

r-52

protons and neutrons

ro-5

two neutrons
2
drops by 4

r-5

nucleons
charges

r-19

energy
charge nor mass

r-33

I
not changed

r-47

protons and neutrons

rQ-10 An electron has the same mass as a ☐ but they have an opposite ☐.

R-10 In beta⁻ and beta⁺ decay the number of nuclear charges is changed. Although the mass number does not change in beta decay, the ☐ does change.

R-24 ${}_{15}P^{32}$ undergoes beta⁻ decay. This means that an ☐ is emitted as one of the 17 ☐ changes to a ☐. The new nucleus contains ☐ charges.

$$\begin{array}{c} 15\ \text{p} \\ \underline{17\ \text{n}} \\ 32\ \text{nucleons} \end{array} \xrightarrow{\text{beta}^-} \begin{array}{c} 16\ \text{p} \\ \underline{16\ \text{n}} \\ 32\ \text{nucleons} \end{array}$$

R-38 An example of beta⁺ decay is when chromium, ${}_{24}Cr^{49}$, changes into vanadium, symbol V. The reaction equation is:

$${}_{24}Cr^{49} \longrightarrow \boxed{} + {}_{+1}e^{0}$$

R-52 You have learned about two particles which each have masses of approximately 1 amu. These are the nucleons, called ☐.

rQ-6 $_{88}Ra^{226}$ emits an alpha particle and becomes radon, Rn. The Z number of radon is [#] and the A number is [#]. The complete symbol is [$]

(143)

$$_{88}Ra^{226} \longrightarrow {}_{2}He^{4} + (?)$$

R-6 If the charges in a nucleus change but not the number of nucleons, either a proton must change into a [ ], or a neutron must [**].

R-20 The neutrino is a peculiar particle that was first detected in 1956. Every beta$^+$ and beta$^-$ decay involves the emission of a [ ] along with either an [*].

R-34 In writing equations for beta decay, the emission of an electron is shown as $_{-1}e^{0}$ and the emission of a positron is shown as [$].

R-48 During beta$^+$ decay a particle not found in the nucleus is emitted. This [ ] charged particle is called a [ ].

rq-9

negatively
positively charged

144

---

r-9

positive
protons
neutron

---

r-23

beta^{-} (beta minus)
decreases

---

r-37

loses (emits)
decreased (reduced)
not

---

r-51

neutrino
photons

rq-6

86

222

$_{86}Rn^{222}$

(145)

r-6

neutron

change into a proton

r-20

neutrino

electron or a positron

r-34

$_{+1}e^{0}$

r-48

positively

positron

rQ-9 In beta$^-$ decay a ______ charged electron is emitted. In beta$^+$ decay a ______ particle called a positron is emitted.

R-9 During beta$^+$ decay, the nucleus loses a ______ charge. This means one of the ______ in the nucleus has changed into a ______.

proton ⟶ neutron + positron

R-23 When an electron is emitted during ______ decay, the charge of the nucleus increases. When a positron is emitted, the charge of the nucleus ______.

R-37 In beta$^+$ decay, the original nucleus ______ one positive charge so its Z number is ______ but its A number does ______ change.

R-51 During beta decay a bundle of energy called a ______ is emitted. Bundles of energy also make up gamma rays, but these are called ______.

rQ-7 In gamma decay only some excess [ ] is emitted. In alpha decay an [•] consisting of [#] nucleons is emitted.

R-7 A nucleus which has 15 protons and 17 neutrons has a total of [#] nucleons. If one neutron changed into a proton, there would still be [#] nucleons.

R-21 Beta decay results in a change in the number of positive [ ] in the nucleus, but does not change the total number of [ ] in the nucleus.

R-35 In a beta decay equation, an electron is shown as [$] and a positron is shown as [$].

R-49 During beta⁻ decay a negatively charged [ ] is emitted. Positrons and electrons have the same small amount of [ ] and have equal but opposite [ ].

rq-8

emitted
beta+

148

---

r-8

not change (not increase or decrease)
would change (would be different)

---

r-22

negative (—) charge

---

r-36

changes (drops)
stays the same (doesn't change)

---

r-50

neutrino
electron (positron)
positron (electron)

rq-7

energy
alpha particle (helium nucleus)
4

149

---

r-7

32
32

---

r-21

charges (protons)
nucleons

---

r-35

$_{-1}e^{0}$
$_{+1}e^{0}$

---

r-49

electron (particle)
mass
charges

rQ-8 In beta decay only Z changes, since no nucleons are ______ from the nucleus. There are two kinds of beta decay, beta$^-$ and •______.

(150)

R-8 If one of the neutrons in a nucleus changed into a proton, the total number of nucleons would •______, but the charge of the nucleus •______.

R-22 In beta$^+$ decay the particle emitted has positive (+) charge. In beta$^-$ decay the particle has a •______.

R-36 Sodium, $_{11}Na^{22}$, beta$^+$ decays and becomes neon, $_{10}Ne^{22}$. The Z number ______, but the A number ••______.

R-50 When either beta$^-$ or beta$^+$ decay occurs, a bundle of energy called a ______ is emitted along with the ______ or ______.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rQ-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER R-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER R-22

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER R-36

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER R-50

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153

UNIT S - Radioactive Dating and Radiation Counters

plus review of Unit R

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER S-4

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER S-18

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER S-32

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER S-46

END OF UNIT

← START HERE

rR-1 During beta decay the total number of ☐ in the nucleus does ☐ change.

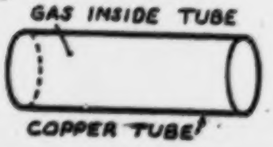
(155)

S-4 Following alpha decay, both the ☐ and the ☐ number of the nucleus are ☐.

S-18 There are 14 decays in the series from $_{92}U^{238}$ to $_{82}Pb^{206}$. The final decay, from $_{84}Po^{210}$ to $_{82}Pb^{206}$ is an ☐.

S-32 The age of materials made from animal or vegetable substances can be determined by ☐.

S-46 A Geiger counter is a copper tube containing some gas. Alpha, beta, and gamma radiations will ☐ some of the ☐ of the gas by knocking electrons loose.



s-3

protons (charges)
higher (increased)

---

s-17

beta$^-$ decays

---

s-31

carbon dating

---

s-45

Geiger
radioactive

---

s-59

Geiger counter (scintillation counter)
scintillation counter (Geiger counter)
radiation

rr-1

nucleons (particles)
not

---

s-4

Z (A)
A (Z)
lower (reduced) (changed)

---

s-18

alpha decay

---

s-32

carbon dating

---

s-46

ionize
atoms

S-3 Beta$^-$ decay results in an increase in the number of ______ in a nucleus. After a beta$^-$ decay, the Z number is always ______.

S-17 By noting the Z and A numbers you can identify the next two decays in the series as both being ______.

$$_{90}Th^{234} \longrightarrow {}_{91}Pa^{234} + (?) \longrightarrow {}_{92}U^{234} + (?)$$

S-31 Measurement of radioactivity is also used in "carbon dating." The age of plant and animal tissue that was once alive can be estimated by a technique called ______.

S-45 A ______ counter is an electrical device that reacts to the ionization produced by the radiations emitted from ______ substances.

S-59 To measure radiation we can use either a ______ or a ______. Both of these devices are types of ______ counters.

rR-2 In beta$^+$ decay a proton changes to a ☐ and a positron is emitted. A ☐ has the same mass as an electron but an opposite ☐.

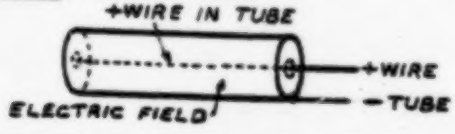
(159)

S-5 If uranium, ${}_{92}U^{238}$, is bombarded by neutrons, and it absorbs one neutron, it becomes a different isotope of uranium, ${}_0n^1 + {}_{92}U^{238} \longrightarrow$ ☐.

S-19 Eventually, all ${}_{92}U^{238}$ nuclei found in nature will decay and this isotope will no longer exist in nature. The other radioactive isotopes in the series will also decay and ☐ ☐.

S-33 Living plants and animals absorb some ${}_6C^{14}$, a radioactive ☐ of the element carbon. In time, ${}_6C^{14}$ undergoes ☐ decay and becomes nitrogen, ${}_7N^{14}$.

S-47 Terminals from a source of high voltage electricity are connected to the tube and to a wire which runs through the tube. This produces an electric ☐ inside the tube.



s-2

changes to a proton
electron

---

s-16

alpha decay

---

s-30

the (relative) amounts of $_{92}U^{238}$ and lead $_{82}Pb^{206}$ in uranium ore

---

s-44

gamma rays
Geiger counter (radiation counter)

---

s-58

more (greater)
is highly radioactive

rr-2

neutron
positron
charge

s-5

$_{92}U^{239}$

s-19

no longer exist in nature (change to other isotopes)

s-33

isotope
beta$^-$ (radioactive)

s-47

field

S-2 Beta$^-$ decay is more common in heavier elements than beta$^+$ decay. In beta$^-$ decay, a neutron • ________ and an ________ is emitted.

162

S-16 The radioactive series in which $_{92}U^{238}$ changes to $_{82}Pb^{206}$ involves both alpha and beta$^-$ decays. The first decay, $_{92}U^{238} \longrightarrow {}_{90}Th^{234} + (?)$ is an • ________.

S-30 The age of the earth has been estimated from the age of uranium ore by measuring •• ________ ________. Calculated this way, the earth is about 4.7 billion years old.

S-44 Alpha, beta, and gamma rays are all emitted by radioactive substances, but only the • ________ are very penetrating and likely to be detected by a • ________.

S-58 A highly radioactive substance emits ________ radiation than a less radioactive substance. A very rapidly clicking counter indicates that a substance •• ________.

(163)

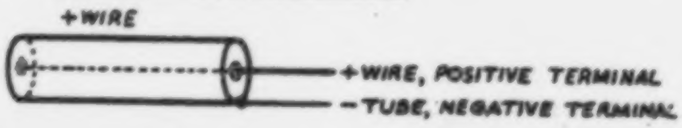
rR-3 In beta$^+$ decay a positive charge is emitted and the Z number drops as a [   ] changes to a [   ].

S-6 The isotope which results from the reaction $_0n^1 + {}_{92}U^{238} \longrightarrow {}_{92}U^{239}$ will emit radiations, which means it is a [   ] nucleus. This new nucleus will undergo beta$^-$ decay.

S-20 Every isotope in the $_{92}U^{238}$ to $_{82}Pb^{206}$ series is constantly changing to another [   ]. Eventually all the original $_{92}U^{238}$ nuclei become [$] nuclei.

S-34 Radioactive $_6C^{14}$ exists in small quantities in the air and is absorbed by all living [   ] and [   ]. When they die, they stop absorbing [$].

S-48 A Geiger counter is constructed so that it has a positive and a negative terminal. The space between these terminals is called an [   ].



s-1

protons (charges)
atomic (Z)

s-15

nucleons

s-29

relatively large amount of uranium (as compared with lead) in uranium ore

s-43

Geiger counter (radiation counter)
radioactivity (radiations)

s-57

greater the number of clicks

rr-3

proton
neutron

165

s-6

radioactive (unstable)

s-20

isotope (element)
$_{82}Pb^{206}$

s-34

plants
animals
$_{6}C^{14}$

s-48

electric field

S-1 Both alpha decay and beta decay result in a change in the number of [   ] in a nucleus and thus a change in the [   ] number.

S-15 The uranium series of decays begins with ${}_{92}U^{238}$ and ends with ${}_{82}Pb^{206}$. By comparing mass numbers, you know that during this series, a total of 32 [   ] are emitted.

S-29 A relatively large amount of lead in uranium ore would indicate that the earth is old, but a [**   ] would indicate it is fairly young.

S-43 Prospectors and people working with radioactive substances often use a [*   ] to measure [   ].

S-57 Each burst of current produces one "click" in a loud speaker. The greater the number of radiations striking a counter, the [**   ].

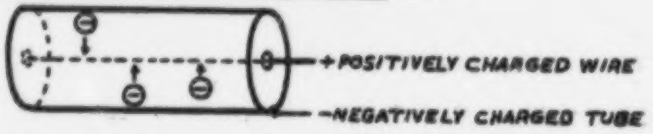
rR-4 When a nucleus undergoes beta decay a [ ] charged electron is emitted and the nucleus gains a [ ] charge as a neutron [**].

S-7 When $_{92}U^{239}$ beta$^-$ decays, the atomic number of the new nucleus is [ ] to [#]. This new element, which contains [#] protons does not exist in nature.

S-21 Uranium ore originally consisted of isotopes of only [#] element, uranium. Because $_{92}U^{238}$ decays to $_{82}Pb^{206}$, however, 14 isotopes of eight different [ ] are found in uranium ore.

S-35 Living organisms absorb $_6C^{14}$, a [ ] isotope of carbon, but when they die, they no longer [*].

S-49 An electric [ ] exerts a force on charged particles. Electrons knocked loose from atoms will be [ ] by the [*] wire.



rr-11

Z
A
change either Z or A

---

s-14

stable
lead ($_{82}Pb^{206}$)

---

s-28

$_{92}U^{238}$
lead
age of the ore (age of the earth)

---

s-42

Geiger counter
radioactivity (radiation)

---

s-56

Geiger counter (scintillation counter)
scintillation counter (Geiger counter)

rr-4

negatively
positive
changes to (becomes) a proton

---

s-7

increased (changed)
93
93

---

s-21

one
elements

---

s-35

radioactive (unstable)
absorb any ${}_{6}C^{14}$

---

s-49

field
attracted
positively charged

rR-11 Alpha decay reduces both Z and A, beta decay changes $\boxed{\$\quad\quad}$ but not $\boxed{\$\quad\quad}$, and gamma emission does not $\boxed{**\quad\quad\quad\quad\quad\quad\quad\quad}$.

S-14 $_{82}Pb^{206}$ is a stable isotope of lead. Natural $_{92}U^{238}$ decays through a series of 14 radioactive isotopes of 8 different elements, finally becoming a $\boxed{\quad\quad\quad\quad}$ isotope of $\boxed{\quad\quad\quad\quad}$.

$$_{92}U^{238} \xrightarrow{\text{Series of decays}} {}_{82}Pb^{206}$$

S-28 By measuring the relative amounts of uranium, $\boxed{\$\quad\quad}$ and $\boxed{\quad\quad\quad}$. $_{82}Pb^{206}$ in a piece of uranium ore, it is possible to estimate the $\boxed{*\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad}$.

S-42 One kind of radiation counter is called a Geiger (guy-ger) counter. A $\boxed{*\quad\quad\quad\quad\quad\quad\quad}$ detects and measures $\boxed{\quad\quad\quad\quad\quad\quad\quad}$.

S-56 The bursts of current produced in either a $\boxed{*\quad\quad\quad\quad\quad\quad\quad}$ or a $\boxed{*\quad\quad\quad\quad\quad\quad\quad}$ may be fed to a meter or a loud speaker.

rR-5 If a nucleus undergoes beta$^-$ decay, the new nucleus would contain one [ ] proton and one [ ] neutron.

(171)

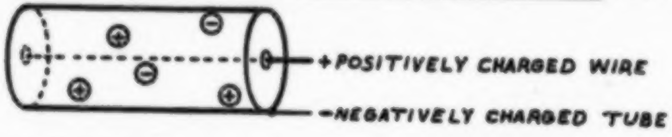
S-8 When ${}_{92}U^{239}$ beta$^-$ decays it becomes neptunium, ${}_{93}Np^{239}$, which is an [ ] not found in nature. The element [ ] is man-made by bombarding ${}_{92}U^{238}$ with [ ].

$${}_0n^1 + {}_{92}U^{238} \longrightarrow {}_{92}U^{239} \longrightarrow {}_{-1}e^0 + {}_{93}Np^{239}$$

S-22 Uranium ore contains all 14 isotopes in the ${}_{92}U^{238}$ to lead, ${}_{82}Pb^{206}$, series. Eventually, only the stable lead isotope, [$], will remain.

S-36 ${}_6C^{14}$ has a [*] of 5,590 years. After a living organism dies, the ${}_6C^{14}$ it contains gradually [ ] and becomes a different [ ].

S-50 When radiations ionize atoms of gas, electrons are attracted to the [ ] charged wire, and positive ions are attracted to the [*] tube.



rr-10

negatively
beta+
positively charged

---

s-13

element
radioactive (unstable)

---

s-27

half-life
ore (earth)

---

s-41

radiation counter
measure

---

s-55

scintillation counter
current (electricity)

rr-5

more
less

(173)

---

s-8

element (isotope)
neptunium
neutrons

---

s-22

$_{82}Pb^{206}$

---

s-36

half-life
decays
element

---

s-50

positively
negatively charged

[illegible]-10 A minus sign (—) indicates a negative charge. In beta$^-$ decay a __________ charged electron is emitted, and in __________ decay a __________ positron is emitted.

S-13 When a radioactive isotope decays, it changes to an isotope of a different __________. In many cases, the new isotope is also __________ which means it too will decay.

S-27 The proportion of $_{92}U^{238}$ remaining in uranium ore depends upon the __________ of $_{92}U^{238}$, which is 4.5 billion years, and upon the age of the __________.

S-41 A device which is sensitive to the presence of radiation is called a __________. These devices are used to detect and __________ the amount of radiation from an object.

S-55 A scintillation (sin-till-ation) counter also detects and counts radiations. Alpha, beta, or gamma rays, striking either a Geiger counter or a __________ produce bursts of __________.

rR-6 Thorium, $_{90}Th^{234}$, beta⁻ decays and becomes proactinium, Pa. The Z number changes from [#] to [#]; but there is no change in the [$] number.

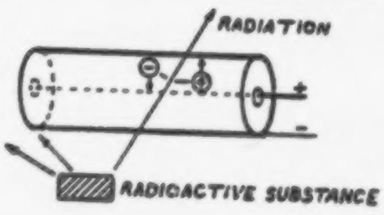
(175)

S-9 $_{93}Np^{239}$ is not stable and it also beta⁻ decays. This causes the number of protons to [ ] from 93 to [#], which forms another [ ] that does not occur in nature.

S-23 Every radioactive isotope has a different half-life. The time required for uranium ore to turn to lead depends on the [•] of all the [•] involved in the decay series.

S-37 The amount of $_{6}C^{14}$ in old wooden objects can be compared to the amount in freshly cut wood. The older, dead wood contains [ ] $_{6}C^{14}$ than the freshly cut wood.

S-51 When an alpha, beta, or gamma ray ionizes [•] [ ] in the tube, electrons are knocked loose from atoms of gas in the tube and move to the [•] [ ].



rr-9

energy
neutrino
mass or charge

s-12

element

s-26

lead
uranium ($_{92}U^{238}$)

s-40

radiation counters

s-54

radiations
many
only a few radiations are striking the Geiger counter

rr-6

90
91
A

---

s-9

increase (change)
94
element

---

s-23

half-life
radioactive isotopes

---

s-37

less

---

s-51

atoms of gas
positively charged wire

rR-9 A neutrino, like a photon, is a bundle of ______. Neither a photon nor a ______ has either * ______ ______.

S-12 In addition to neptunium and plutonium, other elements with Z numbers higher than 92 have been produced by man. Uranium is the heaviest ______ found in nature.

S-26 When the earth was very young, uranium ore contained very little ______, compared to the amount of ______ in it.

S-40 In order to measure the radiation from a piece of ore or wood, a device called a radiation counter is used. Devices to detect and measure radiation are called * ______.

S-54 When many ______ are striking a Geiger counter, ______ bursts of electric current are produced. Very few bursts of current are produced when ** ______ ______.

rR-7 The symbol ${}_{-1}e^{0}$ represents a negatively charged electron. The equation, ${}_{90}Th^{234} \longrightarrow {}_{91}Pa^{234} + {}_{-1}e^{0}$, indicates that thorium undergoes * ________ decay, emitting an ________.

(179)

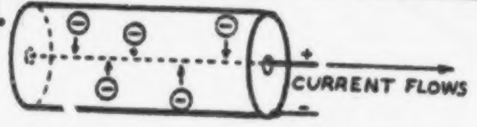
S-10 ${}_{93}Np^{239}$ is radioactive, which means its nuclei are ________. As shown in the equation, neptunium undergoes * ________ to become plutonium, Pu.

$$ {}_{93}Np^{239} \longrightarrow {}_{94}Pu^{239} + {}_{-1}e^{0} $$

S-24 Lead is always found with uranium because ** ________ ________ ________.

S-38 If one gram of fresh wood contains twice as much ${}_{6}C^{14}$ as one gram of old wood, the old wood has been dead for one * ________ of ${}_{6}C^{14}$, about 5,600 years.

S-52 When the electrons strike the wire a small electric current is produced in the wire. This only occurs when radiation has ** ________ ________ ________.



rr-8

neutrino
electron (positron)
positron (electron)

---

s-11

nucleons
mass (A)

---

s-25

$_{92}U^{238}$
lead

---

s-39

the amount of $_{6}C^{14}$ they contain

---

s-53

radiation (ray)
current (electricity)

rr-7

beta minus
electron

s-10

unstable
beta$^-$ decay (radioactive decay)

s-24

uranium (and the other isotopes in the chain) decay and eventually become lead (uranium decays to lead)

s-38

half-life

s-52

ionized atoms of gas in the tube (has passed through the tube) rR-8 During both beta⁻ and beta⁺ decay a neutrino is also emitted. Beta decay always involves the emission of one ________ plus either an ________ or a ________.

S-11 Because there is no change in total number of ________ as the result of beta⁻ decay, $_{92}U^{239}$, $_{93}Np^{239}$, and $_{94}Pu^{239}$ all have the same ________ number.

S-25 The $_{92}U^{238}$ in uranium ore has been there since the earth came into existence. With time, however, some of the $ ________ has become an isotope of ________.

S-39 The age of Egyptian mummies, dinosaur bones, and other objects has been determined by measuring ** ________ ________.

S-53 The current caused by a single radiation flows only briefly. When another ________ passes through the Geiger counter, another brief burst of ________ is produced.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rR-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER S-11

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER S-25

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER S-39

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER S-53

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(185)

UNIT T - Particle Accelerators

plus review of Unit S

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER T-2

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER T-14

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER T-26

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER T-38

END OF UNIT

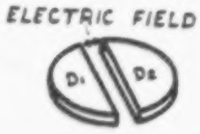
START HERE

rS-1 When a nucleus undergoes beta$^-$ decay, only its ________ number changes. When $_{92}U^{239}$ undergoes beta$^-$ decay, its Z number ________ to ________.

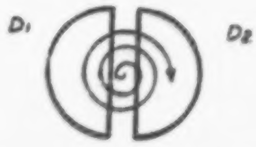
T-2 When nuclei are bombarded by particles and a ________ occurs, the new nuclei formed are sometimes unstable, that is, they are ________.

T-14 Particle accelerators are devices used to increase the ✓ ________ of particles by increasing their velocity. When objects are ________, they go from a lower to a ________ ________.

T-26 The electric ________ exists between the two D's but not inside each hollow D. When charged particles are in the space ________ the D's, a force is exerted on them.



T-38 Each acceleration "whips" the ions into a slightly larger circular path. The ions follow a spiral toward the outside edge of the D's as their ________ increases.



t-1

unstable
decay (change)

t-13

bombard nuclei

t-25

ion
electric field
increased (accelerated)

t-37

cyclotron
electric field
energy

rs-1

atomic (Z)
is increased
93

⑱⑨

---

t-2

nuclear reaction
radioactive

---

t-14

energy
accelerated
higher velocity (higher energy)

---

t-26

field
between

---

t-38

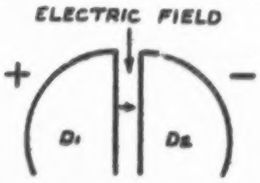
velocity (energy)

T-1 Radioactive isotopes have ☐ nuclei that spontaneously ☐ and become nuclei of a different element.

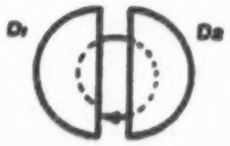
(061)

T-13 Particle accelerators increase the energy of the particles used to ☐ and cause nuclear reactions.

T-25 As a positive ☐ moves through the ☐ between the two D's, it's velocity will be ☐.



T-37 In a ☐, each time an ion passes through the ☐, its velocity, and therefore its ☐ is increased.



END OF UNIT

rS-2 In this reaction, ${}_{92}U^{238}$ is bombarded with a ______ and changes to ${}_{92}U^{239}$, which undergoes * ______ an becomes neptunium, ${}_{93}Np^{239}$.

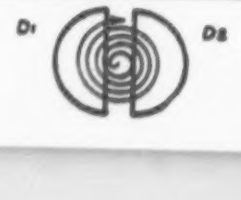
$${}_{92}U^{238} + {}_{0}n^{1} \longrightarrow {}_{92}U^{239} \longrightarrow {}_{93}Np^{239} + {}_{-1}e^{0}$$

T-3 A man-made radioactive isotope is produced by causing a * ______ which results in an atom with an ______ nucleus.

T-15 High energy particles from a particle accelerator are used to ** ______.

T-27 An electric field force is exerted on positive ions only when they are in the space ______ the two $ ______. Inside each D, the ion merely "coasts."

T-39 Ions spiral out toward the outside of the D's as their ______ increases. Ions near the center of the D's have less velocity than ** ______ ______.



rs-11

Geiger counter
ionize

---

t-12

high energy

---

t-24

negative
positive D

---

t-36

attract
will repel them

---

t-48

radioactive isotopes

193

rs-2

neutron
beta$^-$ decay

t-3

nuclear reaction
unstable

t-15

bombard nuclei to produce nuclear reactions.

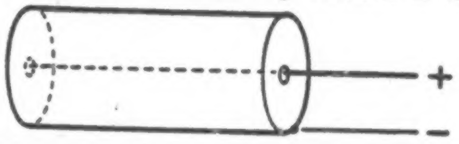
t-27

between
D's

t-39

velocity (energy)
ions near (toward) the outer edge of the D's

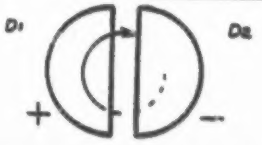
rS-11 This is one kind of radiation counter, a ________ ________. Radiations will ________ atoms of gas in the tube, knocking an electron loose, and allowing current to flow.



T-12 As the velocity of a particle increases, its energy increases. High velocity particles, therefore, are ________ particles.

T-24 A positive ion emitted by the ion source will be attracted by the ________ D and repelled by the ________.

T-36 The electric field is rapidly reversed so that when the positive ions again enter the field, D_2 is negative and will ________ them, and D_1 is positive and ________.



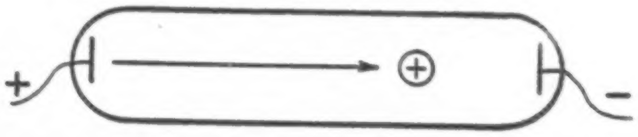
T-48 Particle accelerators are used for nuclear reaction research and to produce ________ which do not exist in nature.

rS-3 An unstable nucleus spontaneously ☐ and changes to a different ☐. All radioactive isotopes eventually will change to isotopes which have ☐ nuclei.

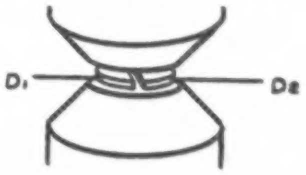
T-4 ${}_7N^{13}$ is a man-made radioactive isotope of the ☐ nitrogen. As shown in this equation, ${}_7N^{13}$ undergoes beta$^+$ decay, emitting a ☐ and becoming ${}_6C^{13}$.

$${}_7N^{13} \longrightarrow {}_6C^{13} + {}_{+1}e^0$$

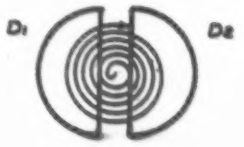
T-16 A positive ion increases in velocity, that is, it ☐, as it moves through an ☐ field from the positive to the negative terminal.



T-28 The magnetic field between the two large ☐ poles exerts a ☐ on ions whether they are inside or between the ☐.



T-40 The size of the spiral path taken by ions increases each trip around. The size of the spiral path increases as the ☐ of the ions is increased.



rs-10

radiation (Geiger)
radiation (particle)

961

t-11

accelerate
velocity

t-23

electric
magnetic field

t-35

negative (opposite)

t-47

cyclotron
bombarding target nuclei with high velocity (energy) particles (to cause nuclear reactions)

rs-3

decays
element (nucleus)
stable

---

t-4

element
positron

---

t-16

accelerates
electric

---

t-28

magnetic
force
D's

---

t-40

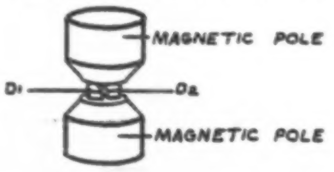
velocity (energy)

TS-10 Radiation can both be detected and measured by a ________ counter. A counter allows a small current to flow when a ________ strikes it.

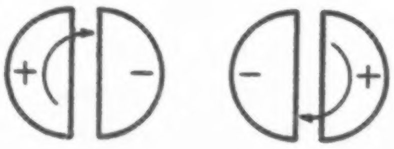
T-11 Particles used to bombard nuclei can be accelerated to high velocities. A particle accelerator is a device used to ________ particles, that is, increase their ________.

T-23 The two D's lie between two large magnetic poles. The D's produce an ________ field, and the magnetic poles produce a * ________.

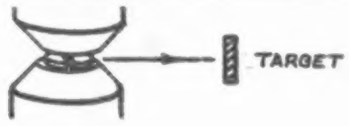
CYCLOTRON



T-35 The D's alternately are made positive and negative so that as positive ions enter the electric field, the D they are approaching always has a ________ charge.



T-47 Man-made radioactive isotopes are produced by using a particle accelerator such as a ________ to ** ________ ________.



CYCLOTRON

rS-4 ${}_{82}\mathrm{Pb}^{206}$ is a stable isotope of lead. ${}_{92}\mathrm{U}^{238}$ decays through a series of 14 isotopes, finally becoming [$], which is a [ ] isotope of the element [ ].

$${}_{92}\mathrm{U}^{238} \xrightarrow{\text{Series of decays}} {}_{82}\mathrm{Pb}^{206}$$

T-5 As shown in this equation, the man-made radioactive [ ] ${}_{7}\mathrm{N}^{13}$ is produced by bombarding ${}_{5}\mathrm{B}^{10}$ with [*] to cause a nuclear reaction.

$${}_{2}\mathrm{He}^{4} + {}_{5}\mathrm{B}^{10} \longrightarrow {}_{7}\mathrm{N}^{13} + {}_{0}\mathrm{n}^{1} + \text{energy}$$

T-17 A positively charged particle will be [ ] each time it passes through an [*] from the positive terminal to the negative terminal.

T-29 There are two fields in a cyclotron. The magnetic [ ] exists inside the D's, while the electric field exists only [**].

T-41 A typical cyclotron has D's which are three or four feet in diameter. Ions cross the [*] 150 or more times, being [ ] each time.

rs-9

carbon dating
half-life

t-10

velocity
increased

t-22

cyclotron
D's

t-34

cyclotron
velocity (energy)
curved path (circular path)

t-46

bombard
high energy (velocity) particles

rs-4

$_{82}Pb^{206}$
stable
lead

t-5

isotope
alpha particles (helium nuclei)

t-17

accelerated
electric field

t-29

field
(in the space) between the D's

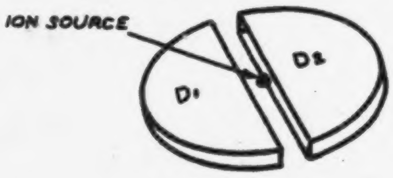
t-41

electric field (between the D's)
accelerated

rS-9 . The age of an Egyptian mummy can be determined by ________, which uses the fact that radioactive $_6C^{14}$ is known to have a ________ of 5,600 years.

T-10 Alpha particles emitted by radioactive substances have relatively low velocities. In order to bombard nuclei with higher velocity alpha particles, the ________ of the particles must be ________.

T-22 The two terminals in a ________ are called D's (dees) because of their shape. Between the two ________ is an ion source.

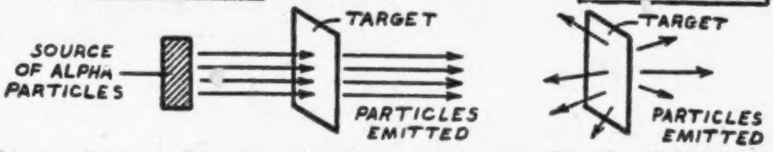


T-34 The electric field in a ________ exerts a force to increase the ________ of the particles while the magnetic field causes them to move in a ________.

T-46 All types of particle accelerators have the same function, to ________ atoms in a target with ________ to cause nuclear reactions.

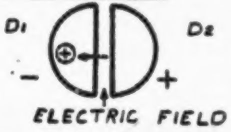
rS-5 Uranium ore contains all radioactive isotopes in the series of decays from $_{92}U^{238}$ to $_{82}Pb^{206}$. Eventually only ** ________ ________.

T-6 Man-made radioactivity was discovered in ________ reaction experiments. It was found that even after the target was no longer being bombarded, ________ in the target continued to ________ particles.

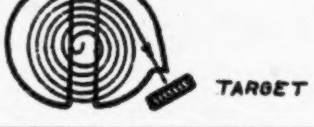

SOURCE OF ALPHA PARTICLES
TARGET
PARTICLES EMITTED
TARGET
PARTICLES EMITTED

T-18 Each time a charged particle moves through an electric field, its energy is ________. If a particle passes through a series of * ________, a very high ________ can be produced.

T-30 As a positive ion is emitted by the ion source, it is ________ to the negative D. Once it goes inside the hollow D, the * ________ no longer exerts a force on it.


D₁
D₂
⊕
−
+
ELECTRIC FIELD

T-42 When the ions reach the outside of the D's they have very high ________. They leave the D's through an opening and can be used to bombard atoms to cause * ________.



rs-8

carbon dating

t-9

velocity

t-21

cyclotron
electric field

t-33

circular (curved) (round)
electric field

t-45

cyclotron
energy (velocity)

rs-5

lead ($_{82}Pb^{206}$) will remain

---

t-6

nuclear
nuclei (atoms)
emit

---

t-18

increased
electric fields
energy (velocity)

---

t-30

attracted
electric field

---

t-42

velocities (energies)
nuclear reactions (radioactive isotopes)

rs-5

lead ($_{82}Pb^{206}$) will remain

t-6

nuclear
nuclei (atoms)
emit

t-18

increased
electric fields
energy (velocity)

t-30

attracted
electric field

t-42

velocities (energies)
nuclear reactions (radioactive isotopes)

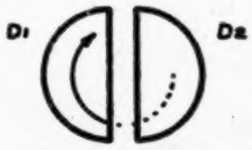
rS-8 Measurement of radioactivity is used in "carbon dating." The age of plant and animal tissue can be estimated by a process called ______.

206

T-9 Many nuclear reactions are likely to occur only when the particles used to bombard nuclei have relatively high velocities. A high ______ increases the likelihood of a reaction.

T-21 In the type of accelerator called the ______ there are only two terminals. The particles that are being accelerated pass repeatedly through the ______ between these two terminals.

T-33 The magnetic field causes the ions to move in a ______ path so they will return to the ______ between the D's.



T-45 In addition to the ______, there are several other kinds of particle accelerators that produce high ______ particles.

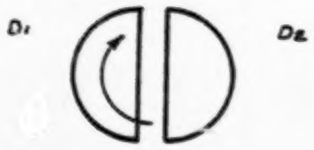
rS-6 The age of the earth can be estimated by comparing the relative amounts of ______ and ______ in uranium ore.

(207)

T-7 Man-made ______ of almost every known element have been produced by bombarding ______ with particles such as $_2He^4$, $_1p^1$ or $_0n^1$. to cause ______ ______.

T-19 A particle accelerator increases the ______ of charged particles by increasing their velocity. Many ______ ______ consist of a series of ______.

T-31 Ions in an electric field will ordinarily travel in a straight path. In a cyclotron, however, the magnetic field causes them to travel in a ______ path.



T-43 By the time the ions reach the outside of the D's, their ______ is very high because they have crossed the ______ many times.

rs-7

they will decay and eventually become stable nuclei

---

t-8

bombarding nuclei with particles to cause a nuclear reaction

---

t-20

accelerator
cyclotron

---

t-32

circular path (circle)
electric field

---

t-44

passes through the electric field

rs-6

uranium
lead

---

t-7

radioactive isotopes
nuclei (atoms)
nuclear reactions

---

t-19

energy
particle accelerators
electric fields

---

t-31

circular

---

t-43

velocity (energy)
electric field

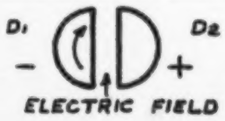
rS-7 Eventually no radioactive isotopes will be found in nature because ** ______________________________ ______________.

012

T-8 Some radioactive isotopes are found in nature. Radioactive isotopes can be made, however, by ** ______________ ______________________________.

T-20 One of the best known type of particle ______________ is the cyclotron. Particles are accelerated in a ______________ because they repeatedly pass through an electric field.

T-32 The magnetic field in a cyclotron causes the ions to move in a * ______________. The ions move through one D then back toward the * ______________ between the D's.



T-44 A cyclotron accelerates ions by using the same electric field over and over again. An ion is accelerated each time it ** ______________________________.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rS-7

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER T-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER T-20

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER T-32

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER T-44